



New LED Lighting in Display Cases at Rosenberg Castle

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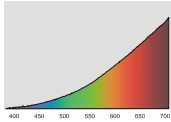
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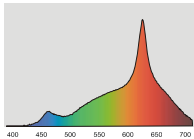
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Department of Photonics Engineering


Technical University of Denmark
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Energy efficient and high quality LED illumination system for display cases







Carsten Dam-Hansen, DTU Fotonik

12. November 2010, NordLED Copenhagen

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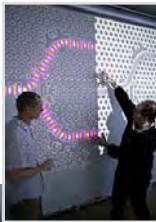
Educational and research institute at the Technical University of Denmark
Telecommunication and optical technologies
190 employees incl. 60 Ph.D.-students
80 M.Sc. candidates and 15 Ph.D students per year

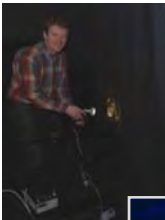
LED group:
Research projects on LEDs, materials and characterisation


Master course on LED and PV technology
Annual Industrial LED conference/workshop

Application specific R&D projects in collaboration with Danish industry and Danish Energy Association

Test & characterisation of LED systems/products









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R&D project

Research and development project on energy efficient and high quality lighting. Collaboration between:

**The Royal Danish Collections, Hazze Nyström
Lumodan, Brian Markussen
DTU Fotonik, Department of Photonics Engineering**

**Financed by the Danish Energy Association under ELFORSK
grant no. PSO 339-029**

Kvorning Design & Kommunikation



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The exhibition display cases



Rosenborg Castle, Copenhagen

**The Royal Danish Collections
Denmark's greatest cultural treasures**

**The Treasury in the
Palace basement**


**Crown Jewels and the
Danish Crown Regalia**

**High security display
cases**



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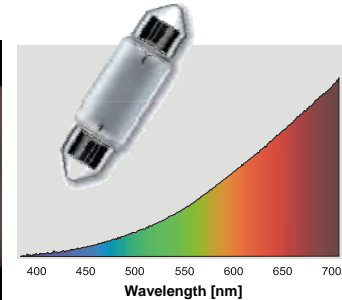
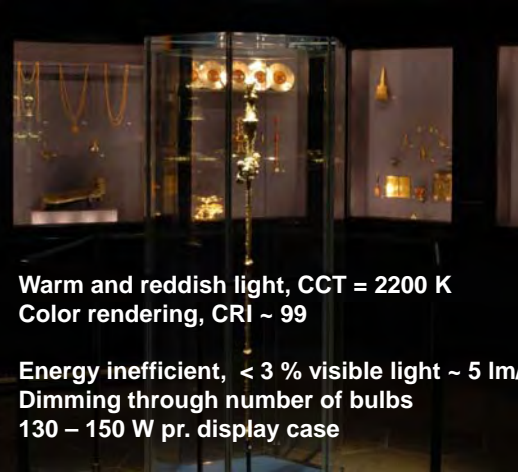


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The present illumination

5 W pinol incandescent bulbs




Warm and reddish light, CCT = 2200 K
Color rendering, CRI ~ 99

Energy inefficient, < 3 % visible light ~ 5 lm/W
Dimming through number of bulbs
130 – 150 W pr. display case

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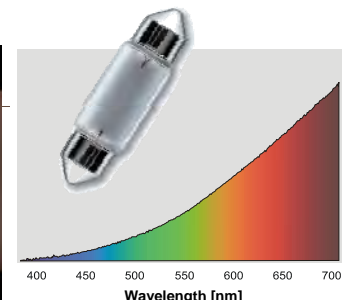
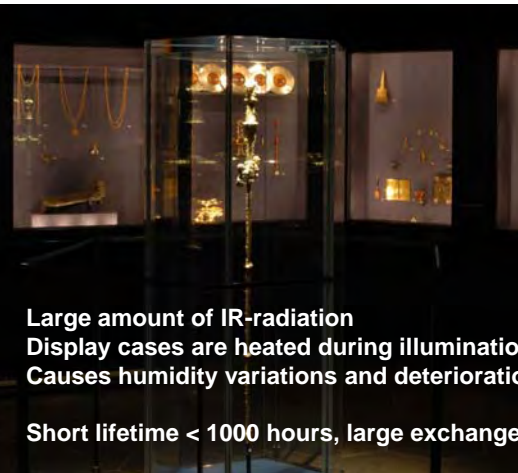


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The present illumination

5 W pinol incandescent bulbs



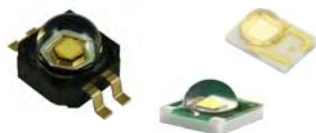
Large amount of IR-radiation
Display cases are heated during illumination, 9-12 deg.
Causes humidity variations and deterioration of objects

Short lifetime < 1000 hours, large exchange expenses

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LED as an alternative



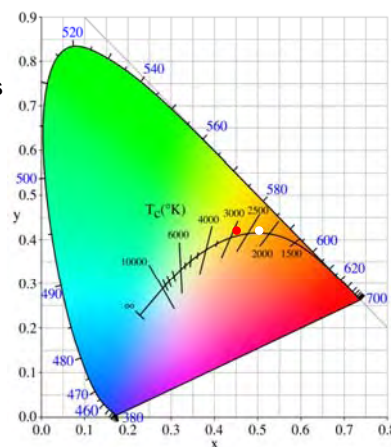
High power LEDs (~ 1-5 W, 50-200 lm)

Compact robust units with high luminous flux and high energy efficiency

Cold and neutral white LEDs
6500 – 3500 K, 104 lm/W

Warm white LEDs
3500 – 2700 K, 81 lm/W

No UV and IR-radiation
Long lifetime 20.000 – 50.000 hours,
if efficiently cooled



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On-site spectral design

Visual inspection and evaluation of spectrally designed LED illumination



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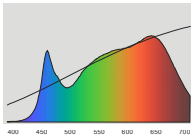
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Spectral design

Visual inspection and evaluation of spectrally designed LED illumination

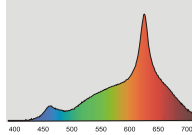


Warm white LED
CCT = 2960 K
Ra = 90





CCT = 2200 K
Ra = 95



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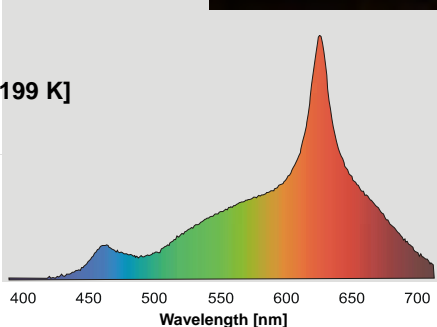

Color quality

Correlated color temperature:
CCT = 2199 K

Color rendering:

Object	Ra _i
1	97.4
2	99.6
3	93.6
4	94.9
5	97.4
6	96.7
7	98.1
8	98.7
9	95.0
10	97.3
11	91.2
12	97.7
13	97.8
14	94.4

CRI = 97.0 [Planckian 2199 K]

Wavelength [nm]

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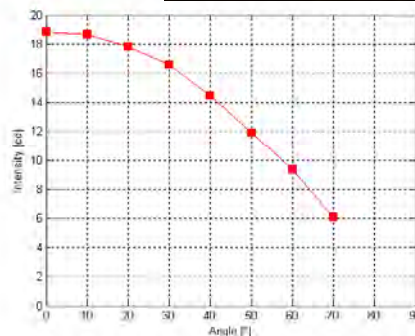
Color quality

Problems with LED color mixing using LED clusters is the appearance of colored shadows

Designed a new optical system:
Mixes the light perfectly and produces diffuse light with no colored shadows

Low efficiency : 50-60 %

Measured intensity as a function of angle, close to a cosine distribution



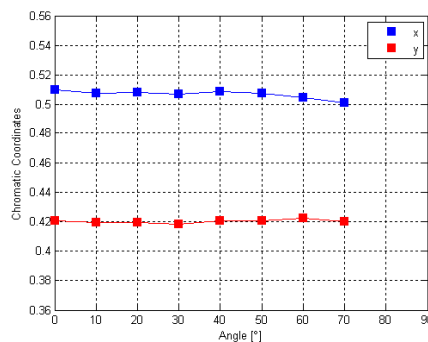
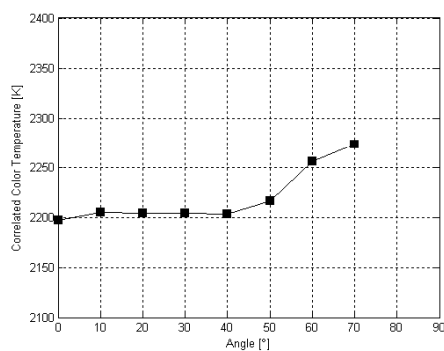
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Color quality

New optical system:
Investigation of the color distribution

Measured chromatic coordinates as a function of angle.




Measured correlated color temperature as a function of angle:
CCT = 2200 K.


Homogeneous light quality with no colored shadows.

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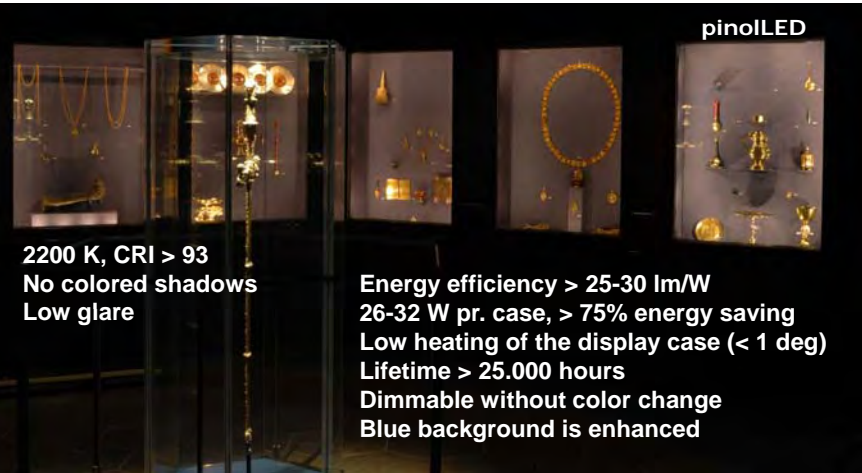
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PinoLED

A new energy efficient and high quality LED illumination system




2200 K, CRI > 93
No colored shadows
Low glare


Energy efficiency > 25-30 lm/W
26-32 W pr. case, > 75% energy saving
Low heating of the display case (< 1 deg)
Lifetime > 25.000 hours
Dimmable without color change
Blue background is enhanced

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PinoLED

LED illumination rail system



Design: Kvorning Design & Kommunikation ©

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PinolLED


Pinol incandescent bulbs

~ 130 W



PinolLED

~ 30 W



DKKS, Kvorning Design & Kommunikation
Lumodan og DTU Fotonik

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